

Operational Parameters, Considerations, and Design Decisions for Resource-Constrained Ion Trap Mass Spectrometers

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Novel Aspect: Investigation of ion trap performance at reduced RF frequency, voltage, qz ejection point and scan speed for resource-constrained instrumentation

Introduction

Mass spectrometers are increasingly finding applications in new and unique areas, often in situations where key operational resources (i.e. power, weight and size) are limited. One such example is the Mars Organic Molecule Analyzer (MOMA). This instrument is a joint venture between NASA and the European Space Agency (ESA) to develop an ion trap mass spectrometer for chemical analysis on Mars. The constraints on such an instrument are significant as are the performance requirements. While the ideal operating parameters for an ion trap are generally well characterized, methods to maintain analytical performance with limited power and system weight need to be investigated and tested.

Methods

Experiments have been performed on two custom ion trap mass spectrometers developed as prototypes for the MOMA instrument. This hardware consists of quadrupole ion trap electrodes that are 70% the size of common commercial instrumentation. The trapping RF voltage is created with a custom tank circuit that can be tuned over a range of RF frequencies and is driven using laboratory supplies and amplifiers. The entire instrument is controlled with custom LabVIEW software that allows a high degree of flexibility in the definition of the scan function defining the ion trap experiment. Ions are typically generated via an internal electron ionization source, however, a laser desorption source is also in development for analysis of larger intact molecules.

Preliminary Data

The main goals in this work have been to reduce the power required to generate the radio frequency trapping field used in an ion trap mass spectrometer. Generally minimizing the power will also reduce the volume and mass of the electronics to support the instrument. In order to achieve optimum performance, commercial instruments typically utilize RF frequencies in the 1 MHz range. Without much concern for power usage, they simply generate the voltage required to access the mass range of interest. In order to reduce the required RF voltage (and power), operation of the ion trap at lower RF frequencies has been investigated. Surprisingly, the performance of the instrument has only been slightly degraded at RF frequencies all the way down to 500 kHz. Mass resolution is relatively stable to this point, and depending on the resonant ejection point used, the peak intensity is also quite stable. To date only masses up to m/z 200 have been fully investigated, however, additional studies are planned to verify the performance with higher mass ions. The lower frequency and voltage should reduce the pseudo potential well depth, eventually affecting the trapping efficiency of the instrument - an effect that could manifest itself in significantly limiting the mass range of trapped ions. Other methods to reduce the RF power while maintaining analytical performance are also under investigation.

This includes ion ejection at lower q_z values to access a given mass with a lower RF voltage. The loss of mass resolution at lower q_{eject} points has been measured and current work is underway to leverage scan speed and the use of non-linear resonances in order to counter this trend. The overall trap performance under this range of operating conditions will be presented with a goal of identifying what trade-offs are acceptable.